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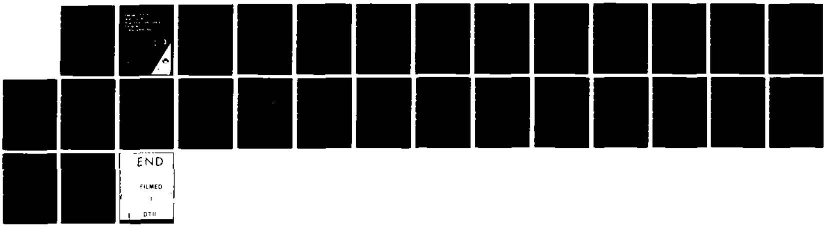

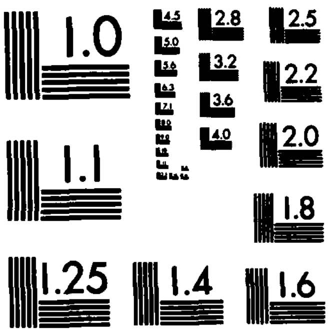

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TECHNICAL REPORT

VARIABILITY IN THE MIXED LAYER DEPTH NEAR THE ICELAND-FAEROE POLAR FRONT DURING SPRING 1981

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JULY 1982

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FOREWORD

This report describes in detail the temporal and spatial variability of the surface mixed layer depth in the Norwegian Sea and Iceland-Faeroe frontal area during the 1981 spring transition period. Detailed knowledge of mixed layer depth variability on scales unobtainable from historical data is critical in addressing Ocean Measurements Program requirements for characterizing the upper ocean environment. Similar analyses addressing these upper ocean environmental characteristics will be performed for other areas of principal interest to the Ocean Measurements Program.

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Captain, USN
Commanding Officer

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Surface mixed layer depths were computed for the spring season in the Norwegian Sea and the Iceland-Faeroe Gap areas using definitions of mixed layer depth based on Brunt-Vaisala frequency and on temperature. The absence of significant gradients in the stratification resulted in mixed layer depths ranging from 10 to 1000 meters, independent of definition. Considerable regional variability in mixed layer depth was found on sub-seasonal time scales.

Acknowledgements

The assistance of Dr. Michael Carron in reviewing this paper is gratefully acknowledged. The illustrations were prepared by Ms. Donna Waters, who also assembled the report for publication. The final manuscript was typed by Ms. Donna Skipper.

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INTRODUCTION

The upper ocean often exhibits a homogeneous layer of water near its surface. The vertical extent of this surface mixed layer is expressed by the mixed layer depth (MLD). Knowledge of the MLD variability is important in understanding the effects of upper ocean processes. Mixed layer depths near the front between Iceland and the Faeroes (Polar Front) and the front on the western side of the Norwegian Current (Norwegian Current Front) have recently been described for summer and early fall by Molinelli, Donelson, and Lilly (1980), and for late fall by Teague and von Zweck (1982). In this region, high temporal and spatial variability in temperature and salinity structure is associated with the fronts, and have been observed in eddies and frontal meanders (Hansen and Meincke, 1979; Kort and Tarasenko, 1977).

Surface mixed layers are commonly defined as isopycnal or isothermal layers extending downward from the surface. These isopycnal and isothermal layers do not necessarily coincide in thickness, especially when the temperature structure is partially compensated by the salinity structure. Mixed layer depths based on temperature are similar to mixed layer depths based on density when the mixed layers are nearly isohaline and are bounded by well-defined seasonal thermoclines. Mixed layer depths are very sensitive to definition when the vertical components of the gradients of temperature and density are small.

During summer and early fall the MLD was relatively independent of region and season near the Polar and Norwegian Current Fronts (Teague and von Zweck, 1982; Molinelli et al., 1980). During the fall-winter transition, however, the MLD near both fronts was strongly dependent on both season and region, with a stronger dependence on region (Teague and von Zweck, 1982). Stratification within the frontal regions was much weaker than outside the frontal regions and sometimes resulted in poor agreement between definitions of MLD within the frontal regions.

This study is an extension into the spring season of the MLD study by Teague and von Zweck (1982) in the region of the polar frontal system. Mixed layer depths based on temperature and density are compared and examined for geographical distribution of MLD for the spring season. Distributions of spring mixed layer depths differ significantly from those obtained for summer and fall. The results of this analysis indicate a complex seasonal and regional variability of mixed layer depth in the Iceland-Faeroe frontal region.

DATA

Data for this study consisted of CTD (Conductivity, Temperature, and Depth) measurements made during April and May 1981 along seven sections in the North Atlantic (figure 1) with a Neil Brown Instrument Systems, Inc., Mark III CTD (Teague, 1981b). The data were

decimated to one-meter depth intervals and low-pass filtered (half-power point at ten meters) prior to deriving mixed layer depths from the resulting temperature and Brunt-Vaisala frequency profiles. Section I was located south of the Polar Front. Section II crossed the Polar Front near Iceland and was divided into three sub-sections: south of the front (section IIA), frontal region (section IIB), and north of the front (section IIC), with portions of sections IIB and IIC being repeated. Sections III, IV, and V crossed the Norwegian Current Front in three parallel transects. Section VI crossed the Polar Front near the Faeroes and Section VII was located just south of the Polar Front and the Faeroes. The spring 1981 CTD station locations were close to those of fall 1980 (Teague, 1981a). The locations of the spring sections I and II (figure 1), in particular, closely corresponded to sections taken across the Polar Front in fall 1980.

With the exception of strongly reduced near-surface variability during the spring, the T-S characteristics of the spring data closely resembled those of the fall. The water south of the front (figures 2a, 2b, and 3d) is characterized by North Atlantic Water near the surface and Arctic Intermediate Water at depth; the gap observed in the T-S diagram (figure 2a) near 35.1 ppt and 6.0 degrees C was due to a weak narrow front encountered at approximately the same location during the fall. This front was located approximately 300 nm southwest of the Faeroes and was oriented roughly northeast-southwest.

The transition into the polar frontal region from the south was marked by a noticeable change in deep T-S characteristics (figures 2c and 3c) over a distance of about 100 nm. The transition from within the frontal region to the region north of the frontal region occurred abruptly over a distance of only several miles. The northern region (figures 2d and 3b) was dominated by North Icelandic Winter and Arctic Intermediate Water at depth, and Norwegian Sea Deep Water near the bottom. The separation in the T-S envelope of the near surface waters was primarily due to the East Icelandic and Irminger Currents. The deep water regime of the northeastern region (figure 3a) was similar to the northern region; however, the North Atlantic Water of the Norwegian Current and low salinity coastal runoff were also evident in the upper ocean.

METHODS

The same two definitions of mixed layer depth (Teague and von Zweck, 1982) used in the fall study are used in this study. The temperature-mixed layer depth (MLD(T)) is defined as the depth at which the absolute value of the temperature gradient exceeds 0.005 degrees C/m and at which the temperature differs by at least 0.15 degrees C from the temperature measured at the top of the profile, usually at a depth of 5 to 10 meters. The stability-mixed layer depth (MLD(N)) is defined as the depth at which the Brunt-Vaisala frequency, N, exceeds a selected threshold, N_0, chosen at 2 cph

In case of multiple relative maxima in N, such as found in a double pycnocline, the first occurrence of the threshold determines MLD(N). The degree of stratification is indicated by NMAX, the value of the first relative maximum in N exceeding N_0. The relative maximum normally corresponds to the absolute maximum of N, and is often found just below the mixed layer.

The choice of appropriate threshold values for both Brunt-Vaisala frequency and temperature is based upon the stratifica n of the area considered. In areas with sharp well-defined seasc thermoclines, and therefore large NMAX, values of N_0 greater t 2 cph, may be appropriate. When NMAX is much greater than N_0, a range of several cycles per hour in N_0 or several tenths of a degree per meter in temperature gradient has little effect upon MLD. For profiles in which the Brunt-Vaisala frequencies do not exceed the threshold N_0, MLD(N) is undefined and the threshold should be reexamined. Since the calculation of N is very sensitive to small changes in density, with the uncertainty increasing for decreasing N, the noise level of the computation should be kept in mind in the selection of the threshold value.

DISCUSSION

Mixed layer depths were calculated using both definitions for each of the seven CTD sections (figure 1). Along the April crossing

of the western end of the Polar Front (sections I and II) mixed layer depths ranged from 20 meters to almost 1000 meters, independent of definition (figures 4 and 5). South of the frontal region (section IIa), a thin mixed layer ranging from 10-20 meters in thickness was present, with differences between mixed layer depths from the two MLD definitions usually between 10 and 30 meters. In the frontal region (section IIB) mixed layer depths ranged from 50 to 1000 meters, with differences resulting from the two MLD definitions of up to 800 meters. North of the frontal region (section IIC) mixed layer depths ranged from 100 to 300 meters; the stability MLD became undefined (N less than the threshold, 2 cph). The degree of stratification as measured by NMAX ranged from below 2 cph to above 5 cph along section II. The value of NMAX was uniformly low, with the largest variation and maximum value of NMAX found near the northern boundary of the frontal region (northern end of IIB).

In the vicinity of the Norwegian Current Front (sections III, IV, and V) resulting mixed layer depths ranged from 20 to 240 meters (figures 6, 7, and 8), often with good agreement between definitions. Mixed layer depths in this region are complicated not only by frontal activity but also by patches of fresher surface water (35 ppt or less), possibly originating from coastal runoff. The observed patches were approximately 10 to 20 meters in thickness and resulted in corresponding shallow mixed layer depths and large values of NMAX (5 to 10 cph).

Mixed layer depths (figure 9a) for the May crossing of the Polar Front near the Faeroes (section VI) were consistent between definitions but were considerably shallower than those resulting from the April crossing near Iceland (section II, figure 5). The shallow MLD, ranging from 10 to 20 meters for all of section VI, is attributed to spring warming. Mixed layer depths for section VII, located south of the Polar Front, ranged from 10 to 60 meters (figure 9b). Changes in the stratification from April (section II) to May (section VI) are shown by contours of temperature, salinity, and sigma-t in figures 10 and 11.

SUMMARY AND CONCLUSION

The stratification observed throughout the Iceland-Faeroe Norwegian Sea area during spring was much weaker than observed in this region during fall. The broad weakly stratified frontal zone observed during fall 1980 could not be readily identified during spring 1981. In fall, typical values of NMAX were between 3 cph and 5 cph in frontal regions and between 6 cph and 13 cph outside of frontal regions. During April, NMAX was typically between 2 cph and 3 cph throughout the area, while in May, NMAX was usually between 3 cph and 5 cph except in the fresh surface layers observed in the vicinity of the Norwegian Current Front where NMAX was between 5 cph and 10 cph. Since mixed layer depths are very sensitive to thresholds in regions of low vertical gradients of temperature or

density, the general interpretation of the mixed layer depth for spring is more complicated than for fall.

Strong regional and seasonal dependence in mixed layer depths were found. In April, as in October and November, mixed layer depths were significantly deeper within the frontal regions than outside the frontal regions. In April mixed layer depths were, however, hundreds of meters deeper than in October and November. In May, mixed layer depths were between 10 and 20 meters along section VI which crossed the Polar Front just west of the Faeroes, while during September mixed layer depths in the same area were between 30 and 50 meters. However, prediction of MLD by season is extremely unreliable in the polar frontal regions since mixed layer depths are forced on time scales less than several weeks (Teague and von Zweck, 1982). Generally, the largest differences in MLD resulting between definitions of MLD were in the frontal regions, where the stratification was weakest.

In the general interpretation of MLD, the vertical and horizontal descriptions of the stratification are important. Small differences in the vertical stratification between profiles can lead to significant differences in MLD. When the maximum stratification is represented by Brunt-Vaisala frequencies of about 2 cph, as was observed in this study, detailed descriptions of MLD are not meaningful. In regions characterized by large vertical gradients in temperature or density, mixed layer depths are relatively insensitive

to definition or to the choice of threshold values. In regions characterized by weak vertical gradients the subjective selection of definition criteria in the absence of an absolute definition may result in large uncertainties in mixed layer depths.

REFERENCES

Hansen, B., and J. Meincke, Eddies and meanders in the Iceland-Faroe Ridge area, Deep Sea Res., 26A, 1067-1082, 1979.

Kort, V., G. and V. M. Tarasenko, Synoptic variability of the Norway Current, Oceanology, 17(4), 379-382, 1977.

Molinelli, E., J. Donelson, and L. Lilly, Mixed Layer Depth Distributions from SVSTD data, Tech. Rep. SAI-81-60-WA, Science Applications, Inc., McLean, VA, 1980.

Teague, W. J., CTD Profiles in the Northeast Atlantic and Norwegian Sea September-November 1980, Data Summary, U.S. Naval Oceanographic Office, Bay St. Louis, MS 1981a.

Teague, W. J., CTD Profiles in the Northeast Atlantic and Norwegian Sea April-May 1981, Data Summary, U. S. Naval Oceanographic Office, Bay St. Louis, MS 1981b.

Teague, W. J., O. von Zweck, Variability in the mixed layer depth near the Polar Front, Technical Report 287, U. S. Naval Oceanographic Office, Bay St. Louis, MS, 1982.

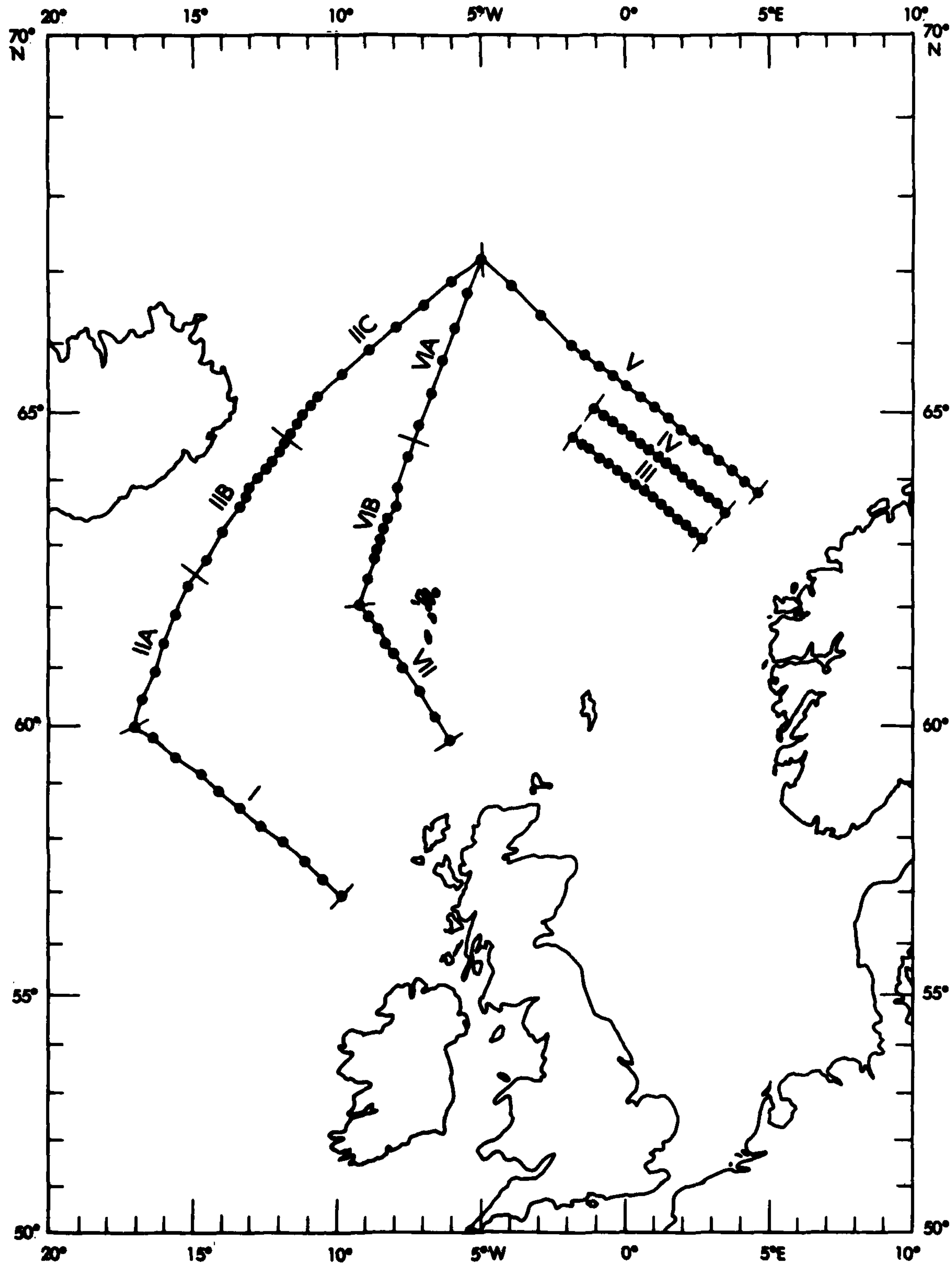


Figure 1 CTD section locations

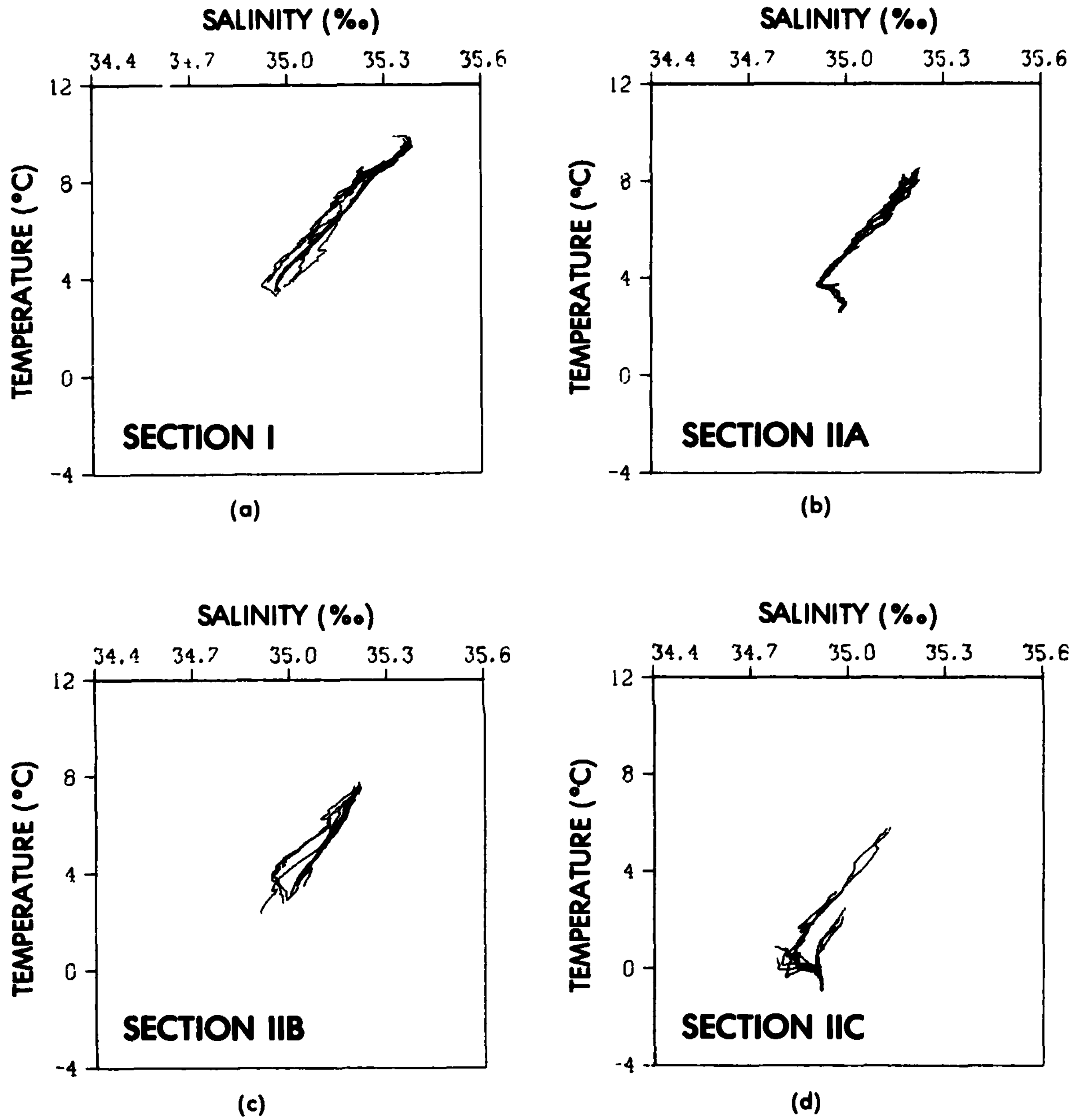


Figure 2 Composite Temperature-Salinity diagrams for Sections I and II

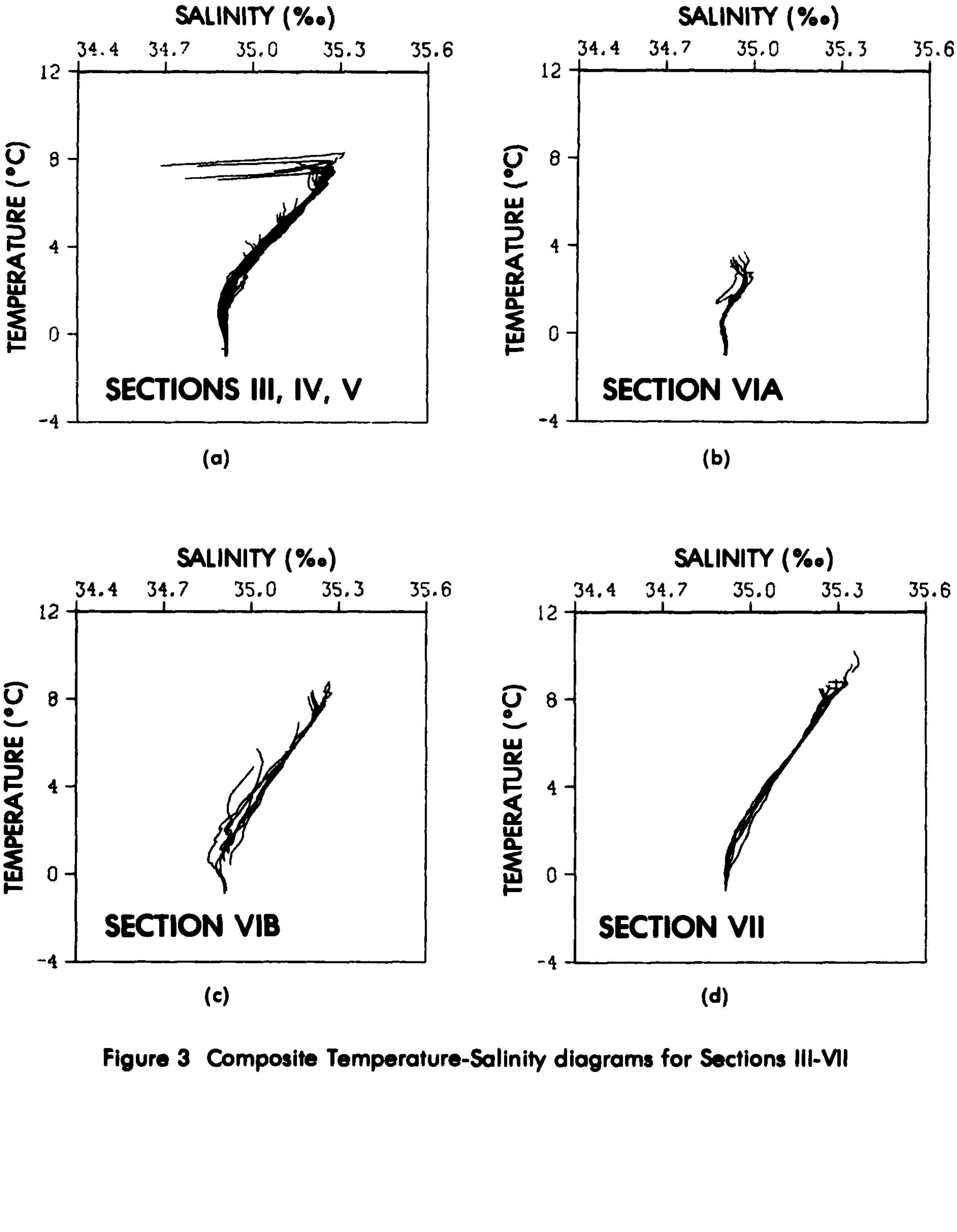


Figure 3 Composite Temperature-Salinity diagrams for Sections III-VII

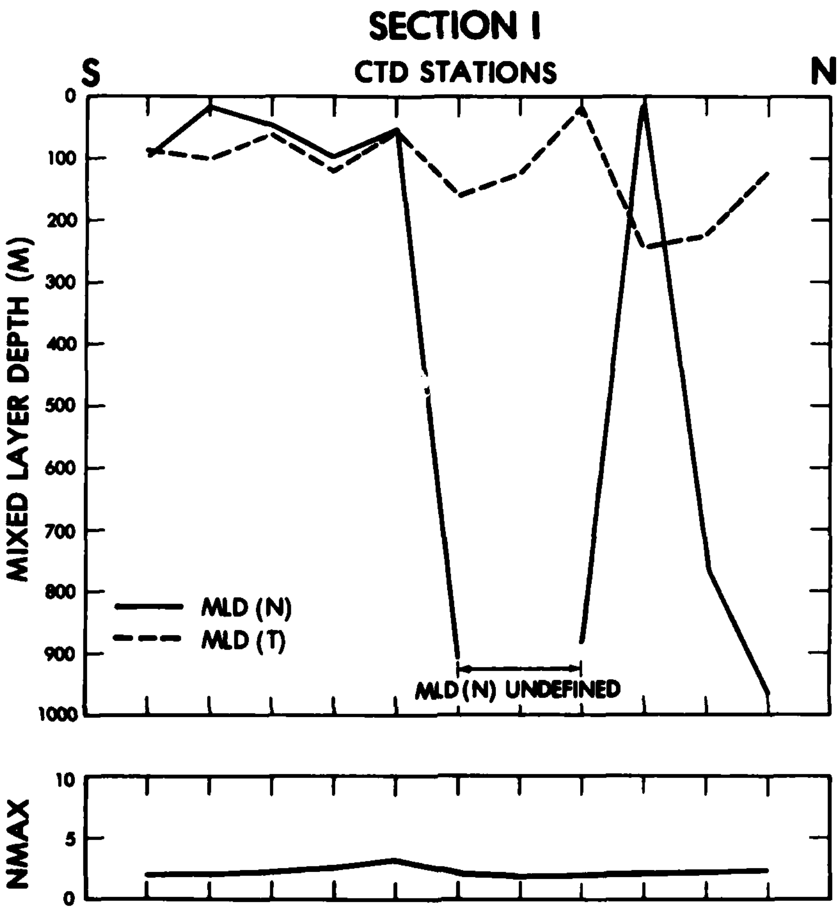


Figure 4 Mixed Layer Depth and NMAX along Section I

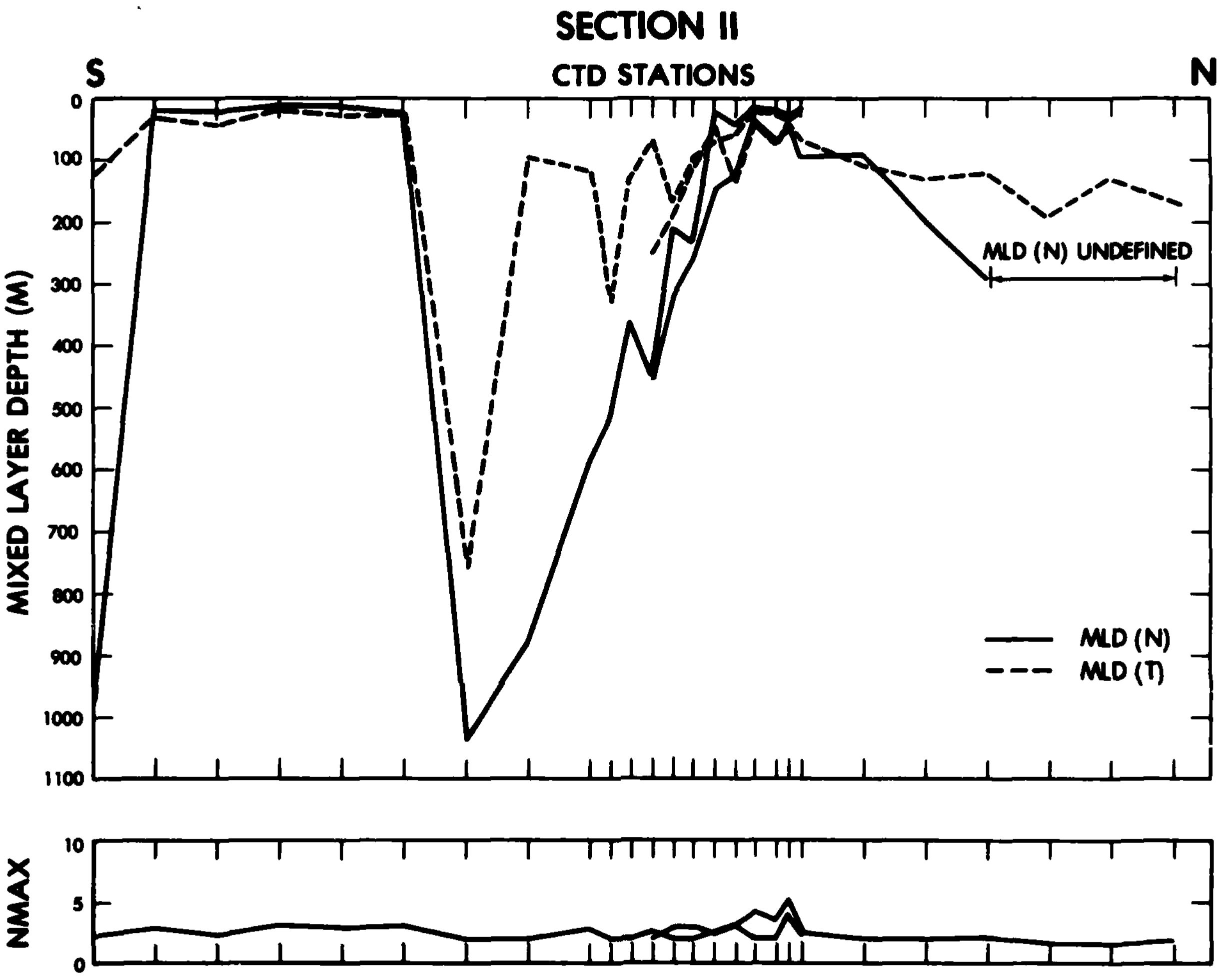


Figure 5 Mixed Layer Depth and NMAX along Section II

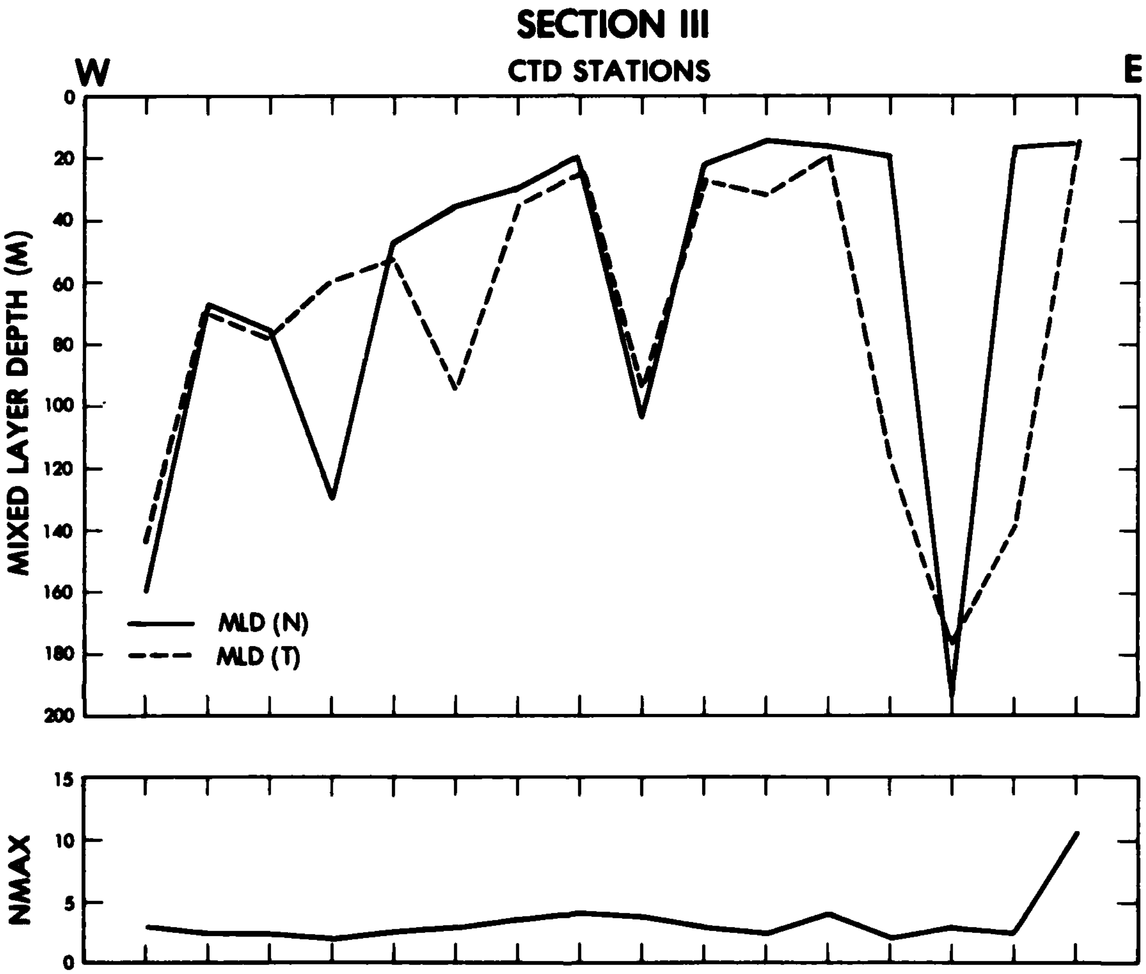


Figure 6 Mixed Layer Depth and NMAX along Section III

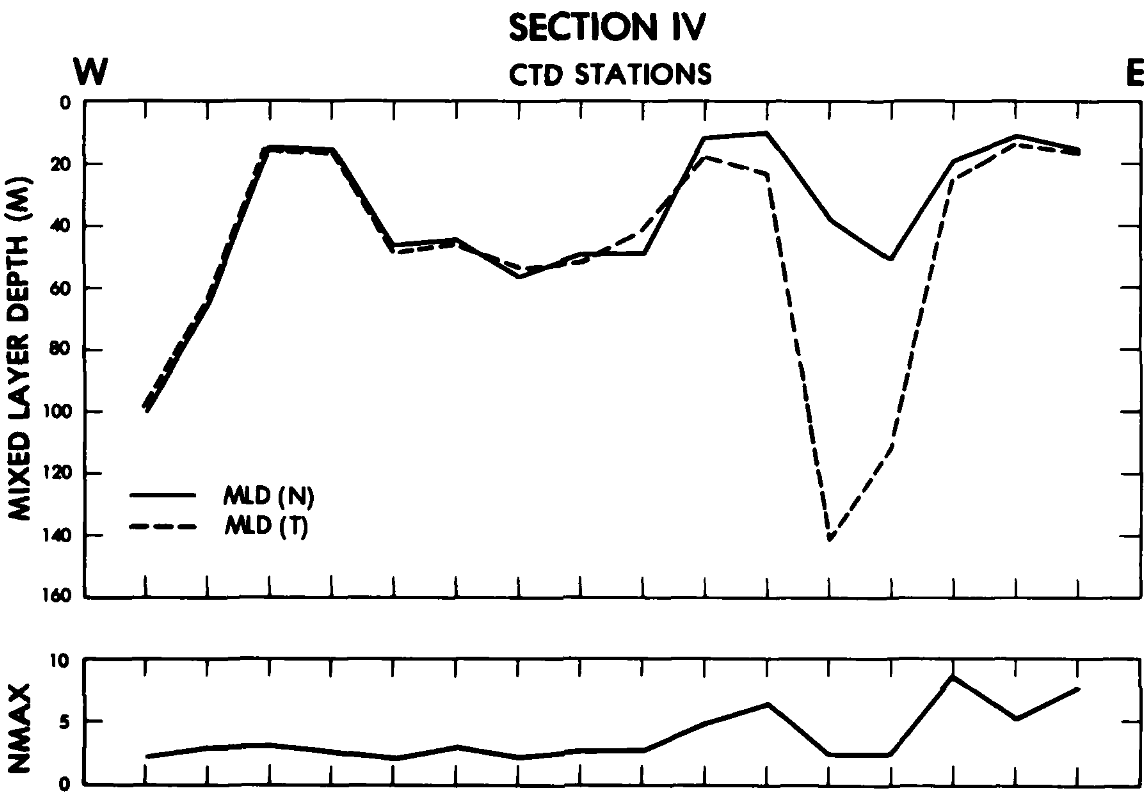


Figure 7 Mixed Layer Depth and NMAX along Section IV

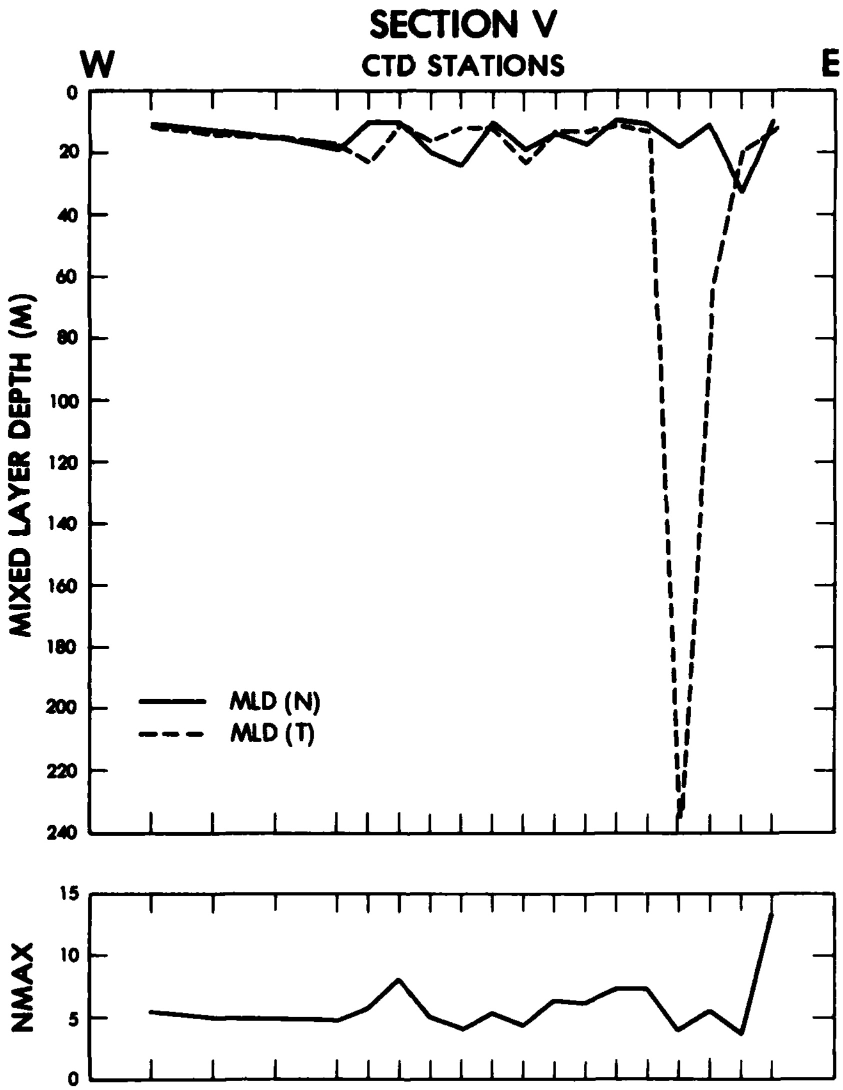
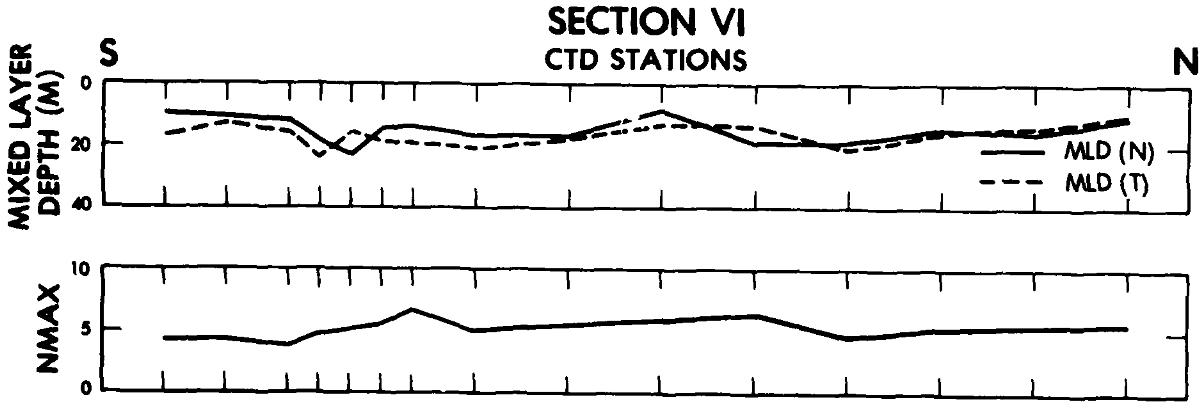
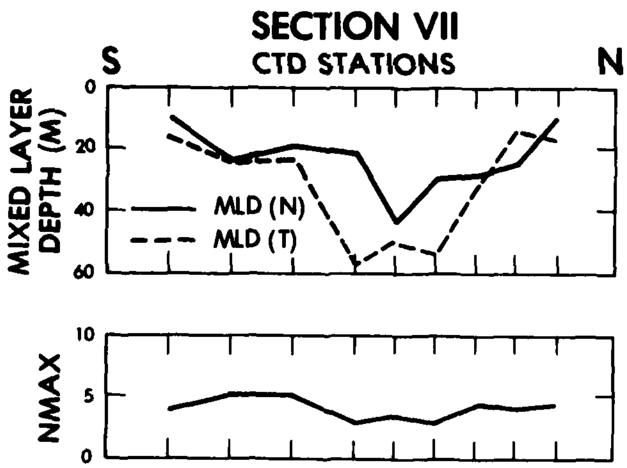


Figure 8 Mixed Layer Depth and NMAX along Section V



(a)



(b)

Figure 9 Mixed Layer Depth and NMAX along Section VI, (a), and Section VII, (b)

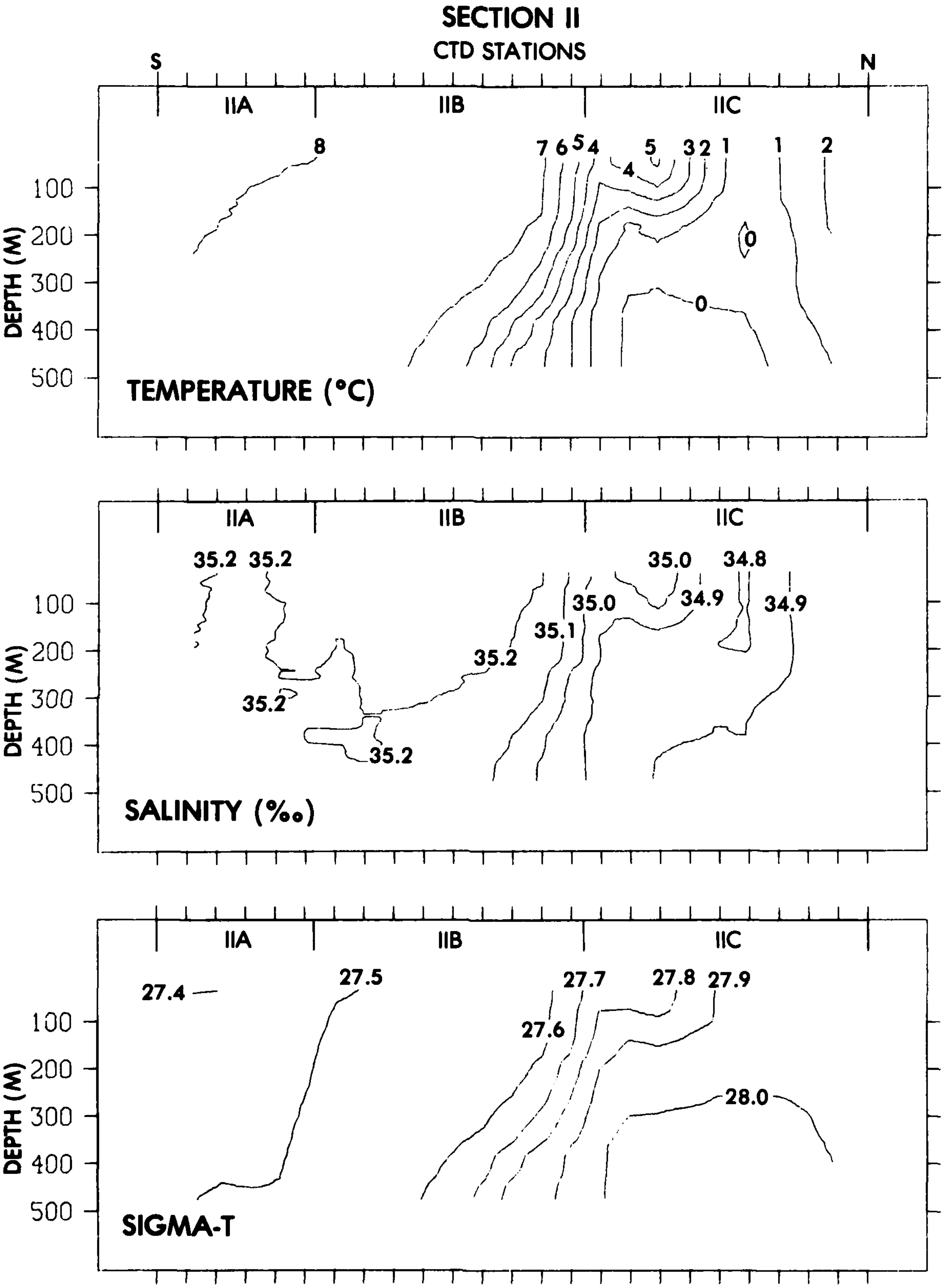


Figure 10 Contours of Temperature, Salinity, and Sigma-t for Section II

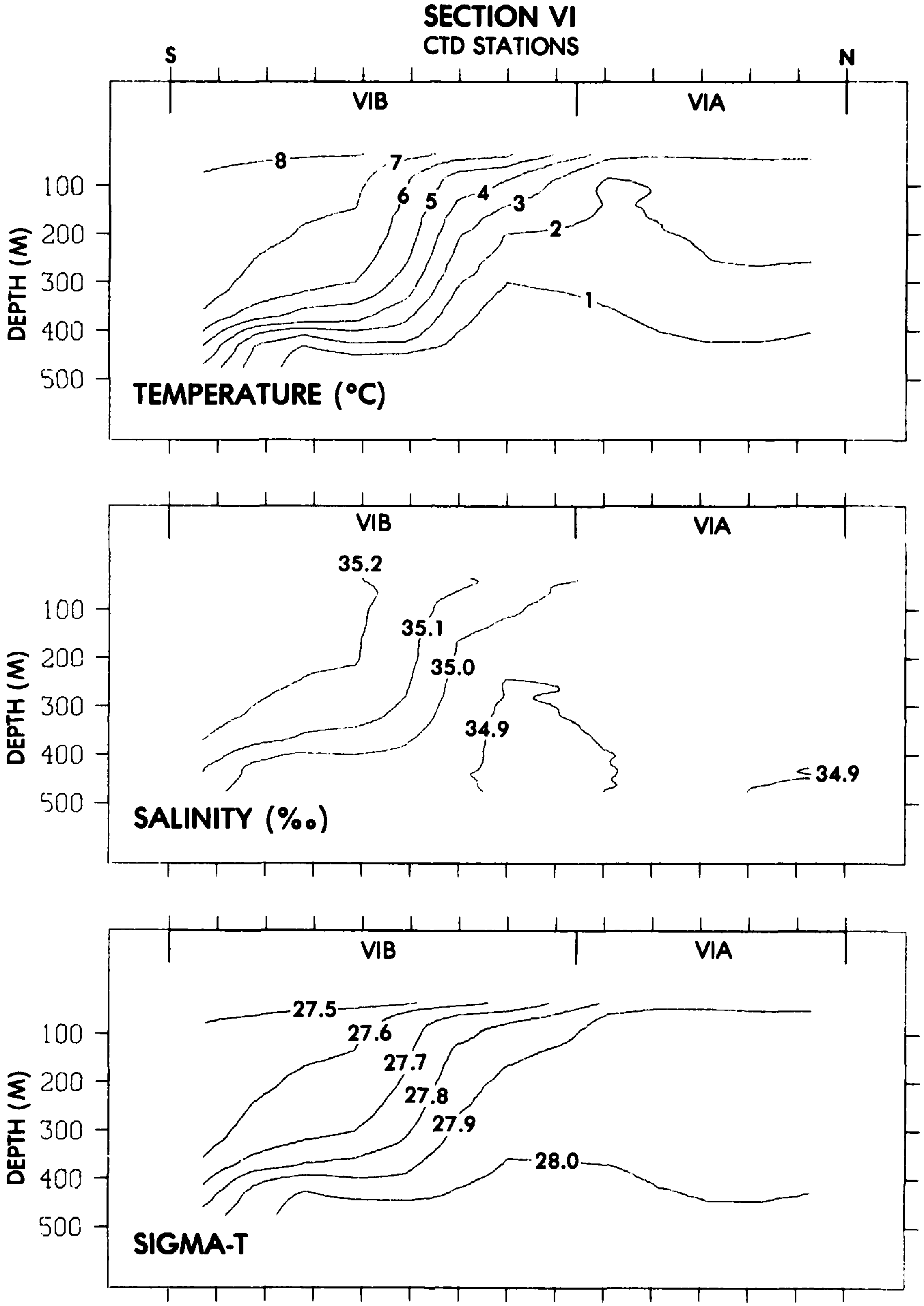


Figure 11 Contours of Temperature, Salinity, and Sigma-t for Section VI

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